Challenge of HTS for future accelerator magnets

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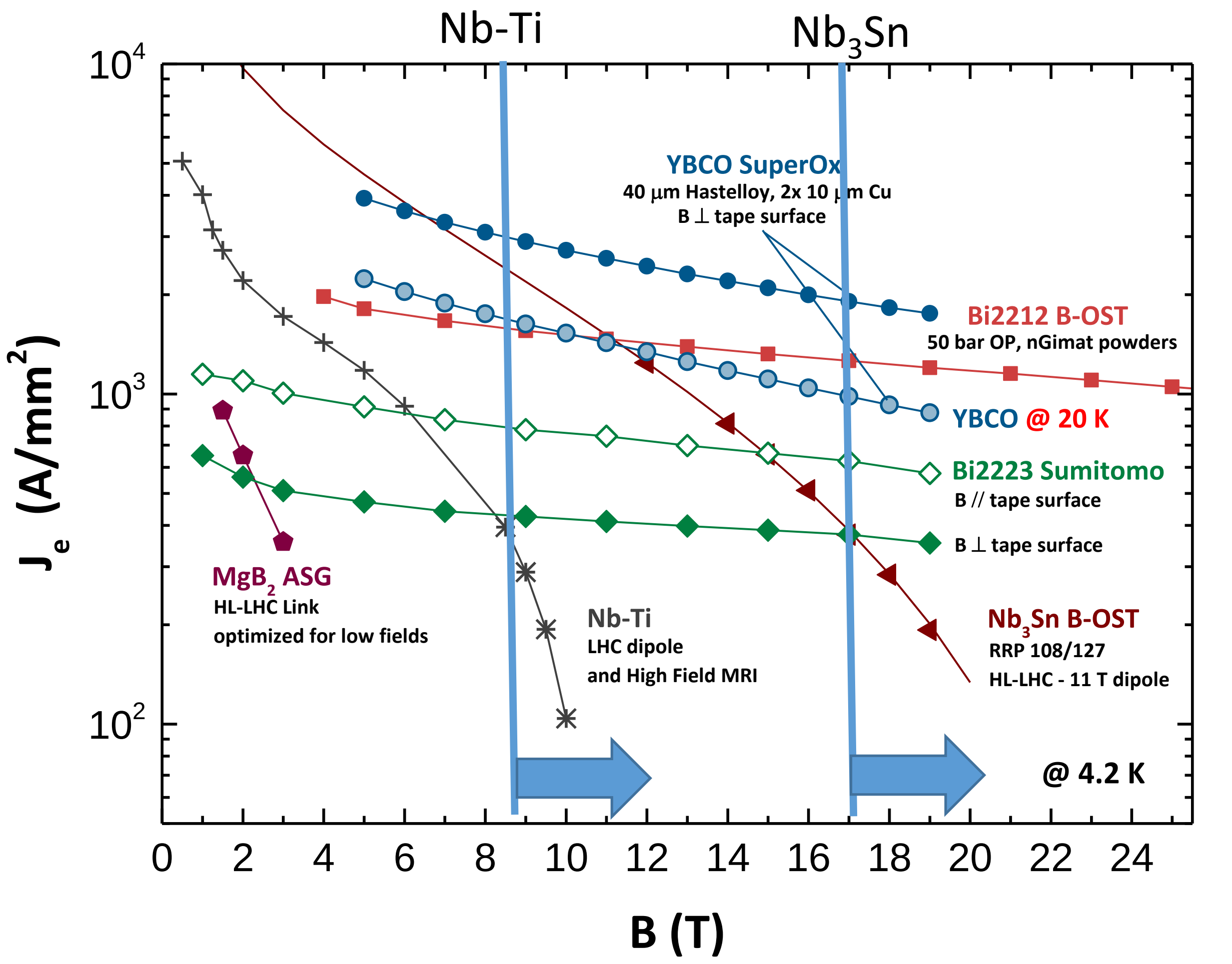
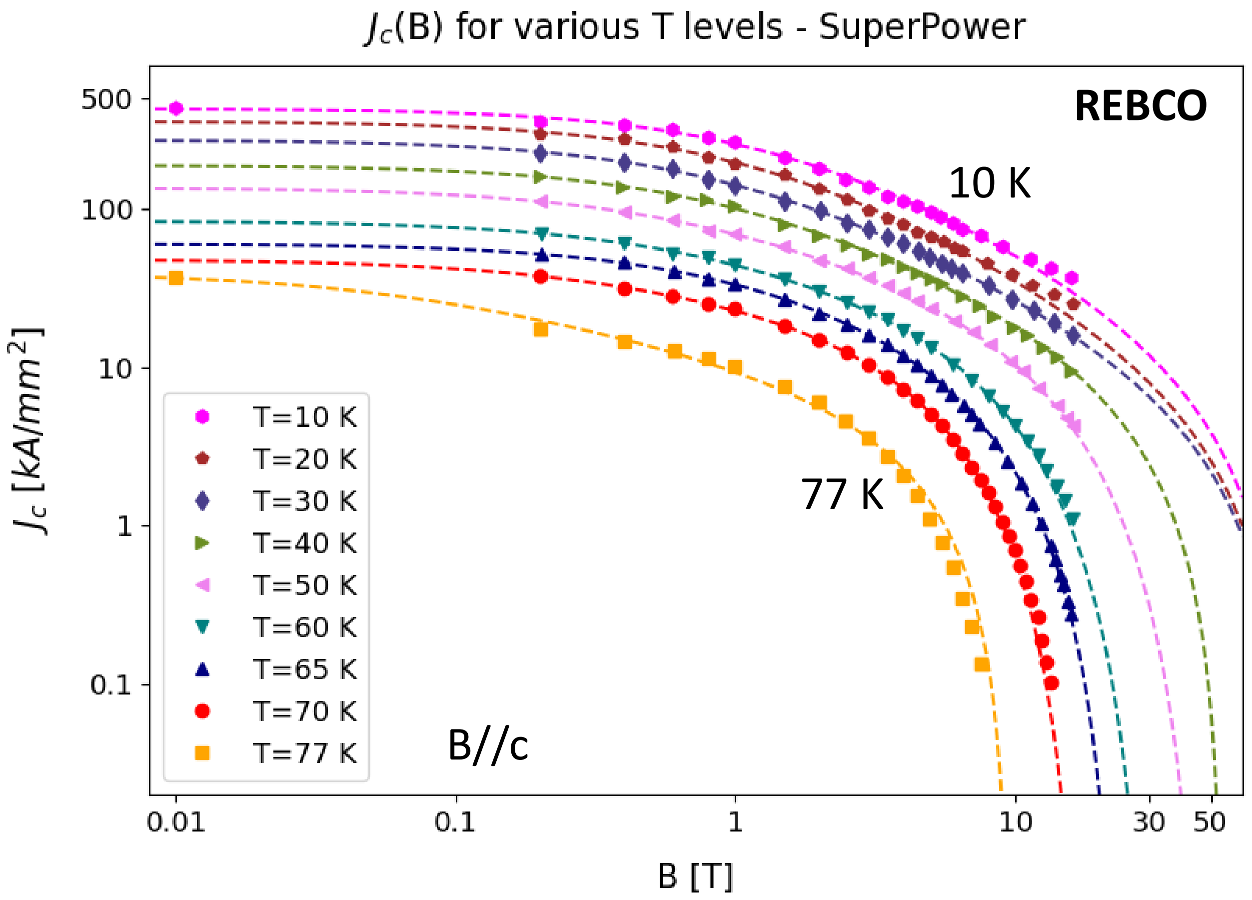
HTS in magnets

High Jc at 4.2 K **and/OR** **Higher temperatures**





HTS in magnets

- The **only choice** for magnetic **fields exceeding ~ 16 T**

- The **only choice** for **operating temperatures > ~ 30 K**

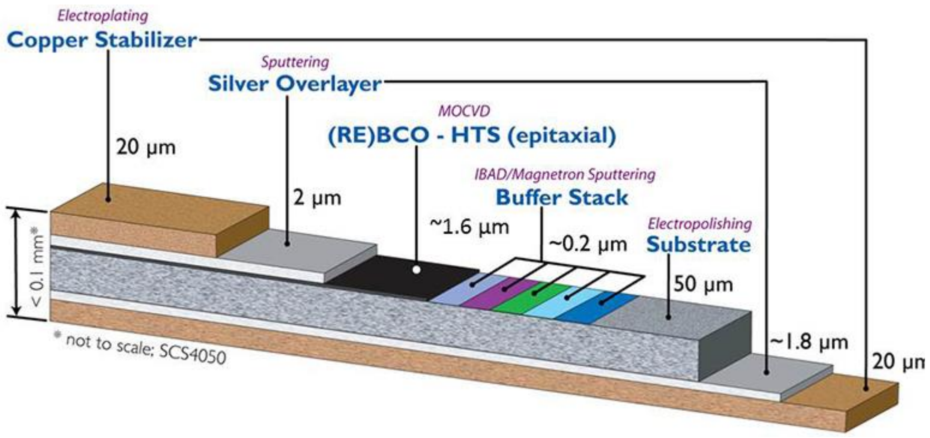
  Indirect cooling, cooling with GHe $\rightarrow$ operation with temperature margin

- An **alternative to LTS** for reducing the cryogenic cost of the refrigeration, e.g. operating at 10 K – 20 K instead of 4.2 K

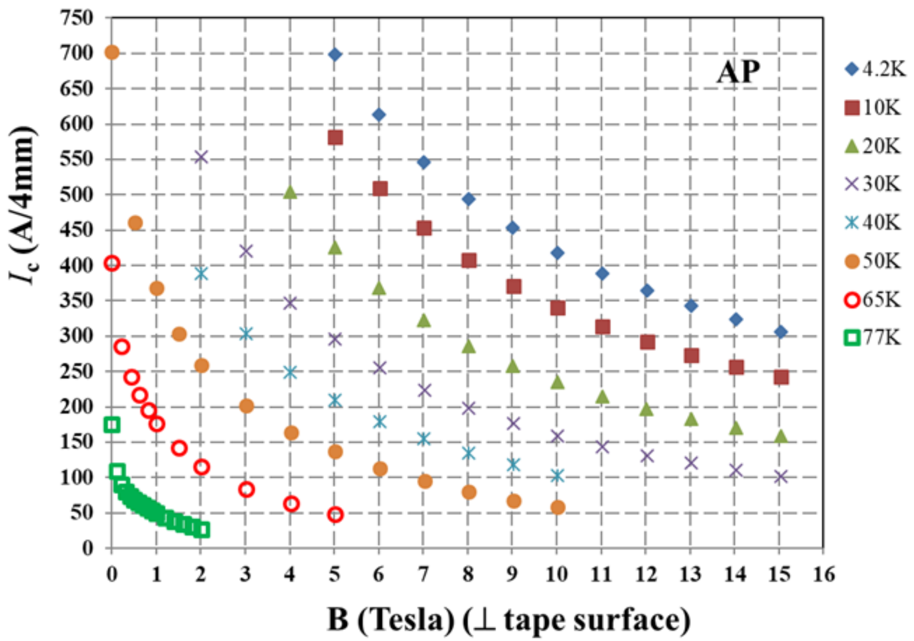
REBCO Conductor

- **REBCO conductor**:
  - **Excellent electrical performance** - no need to further increase Jc
  - **React & Wind** technology
  - Produced by **several manufacturers**

SuperPower Inc.



FURUKAWA ELECTRIC GROUP

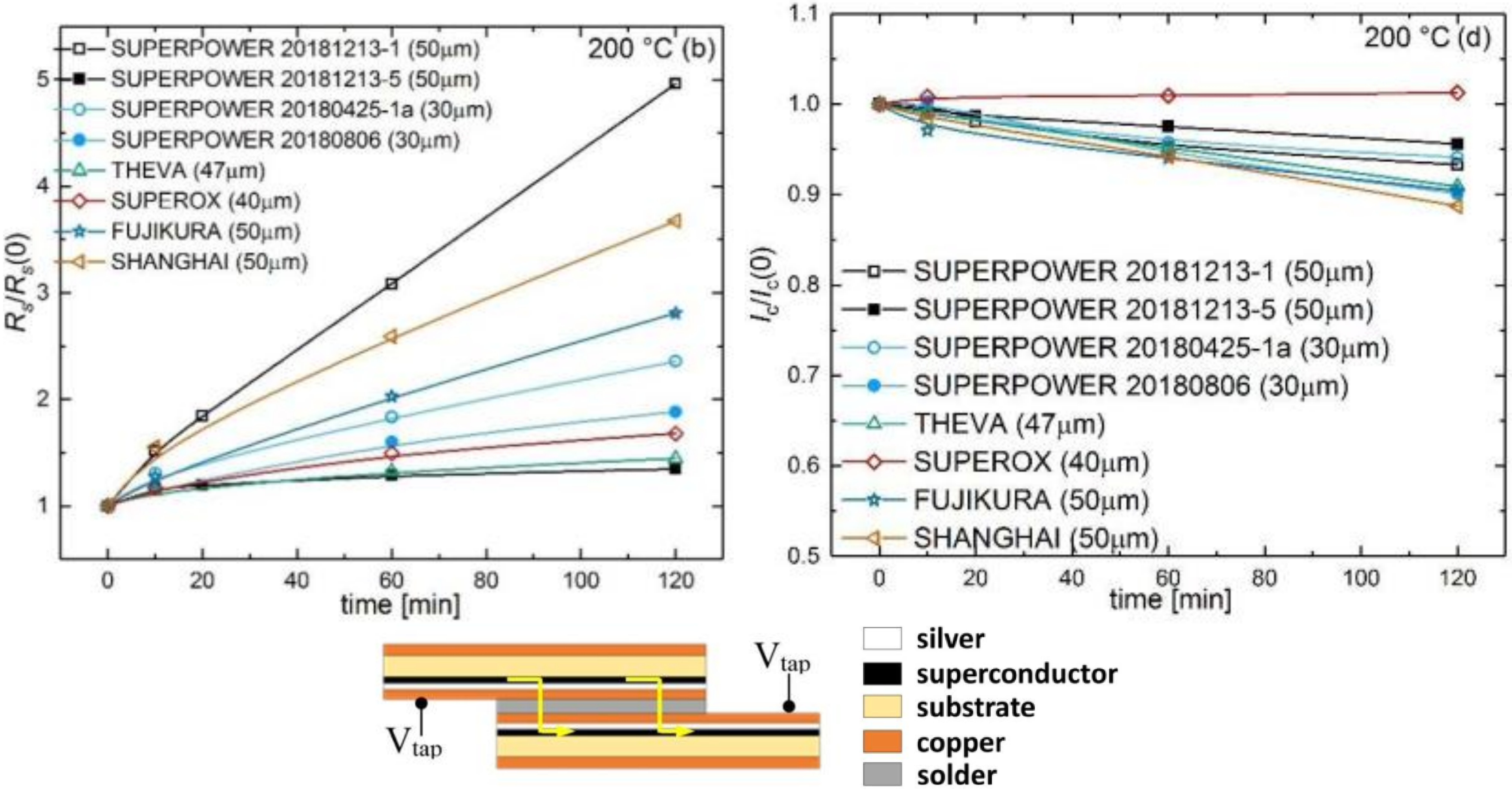


REBCO tape and Coils

Some of the key challenges to be tackled for use of REBCO in accelerator magnets:

- **Field quality** and wide tapes;
- Development of **high-current cables** made from wide tapes (Roebel, stacks of tapes, round cables of twisted tapes,…) – **innovation is required**;
- Choice among **non-insulated**, **partially-insulated** and **insulated coils**. For accelerator magnets, insulated coils are today considered the only option;
- **Quench detection** and **quench protection** – new methods for active protection;
- Protection of **hybrid (LTS + HTS) magnets**;
- Dealing with **anisotropy of REBCO properties** in a coil design;
- **Screening currents in REBCO tapes** – in the low field regions, Lorentz forces and consequent shear/peeling forces;
- Difference in **REBCO performance depending on the manufacturer**;
- Availability of conductor in **long** (km) **lengths**;
- Conductor **cost**;
- …

REBCO Tape and Coils

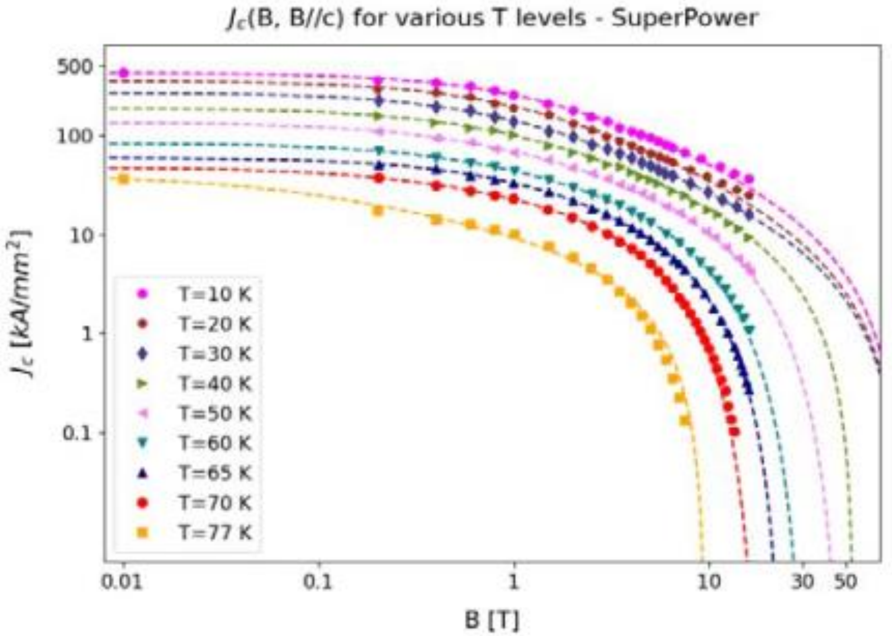


Effect of heating time and temperature on joint resistance of REBCO tapes

I. Falorio, et al, CERN EDMS N. 2366622

REBCO Tape and Coils

- Scaling laws for REBCO conductor



$$I_c(B,T=T^*,\theta=\theta^*) = I^*_{c,0}\cdot\left(1+\frac{B}{B^*_0}\right)^{-\alpha^*}\cdot\left(1-\frac{B}{B^*_{irr}}\right)^{q^*}$$

$$I_c(B,T,\theta) = I_0(T)+\sum_{k=1}^{n}\frac{I_{c,k,0,0}\cdot\left(1-\frac{T}{T_{c,k}}\right)^{\gamma_k}\cdot\left[1+\frac{B}{B_{0,k}(T)}\right]^{-\alpha_k(T)}\cdot\left[1-\frac{B}{B_{irr,k}(T)}\right]^{q_k(T)}}{\omega_k(B)\cdot\varepsilon[\omega_k(B);\,\theta-\varphi_k]}$$

Scaling law for the magnetic field, temperature, and angular dependence of the critical current of REBCO coated conductors

G. Succi et al, CERN EDMS N. 2747837

- Modelling and analysis tools for HTS magnets

European Strategy Update

European Strategy Update

Laboratory Directors Group

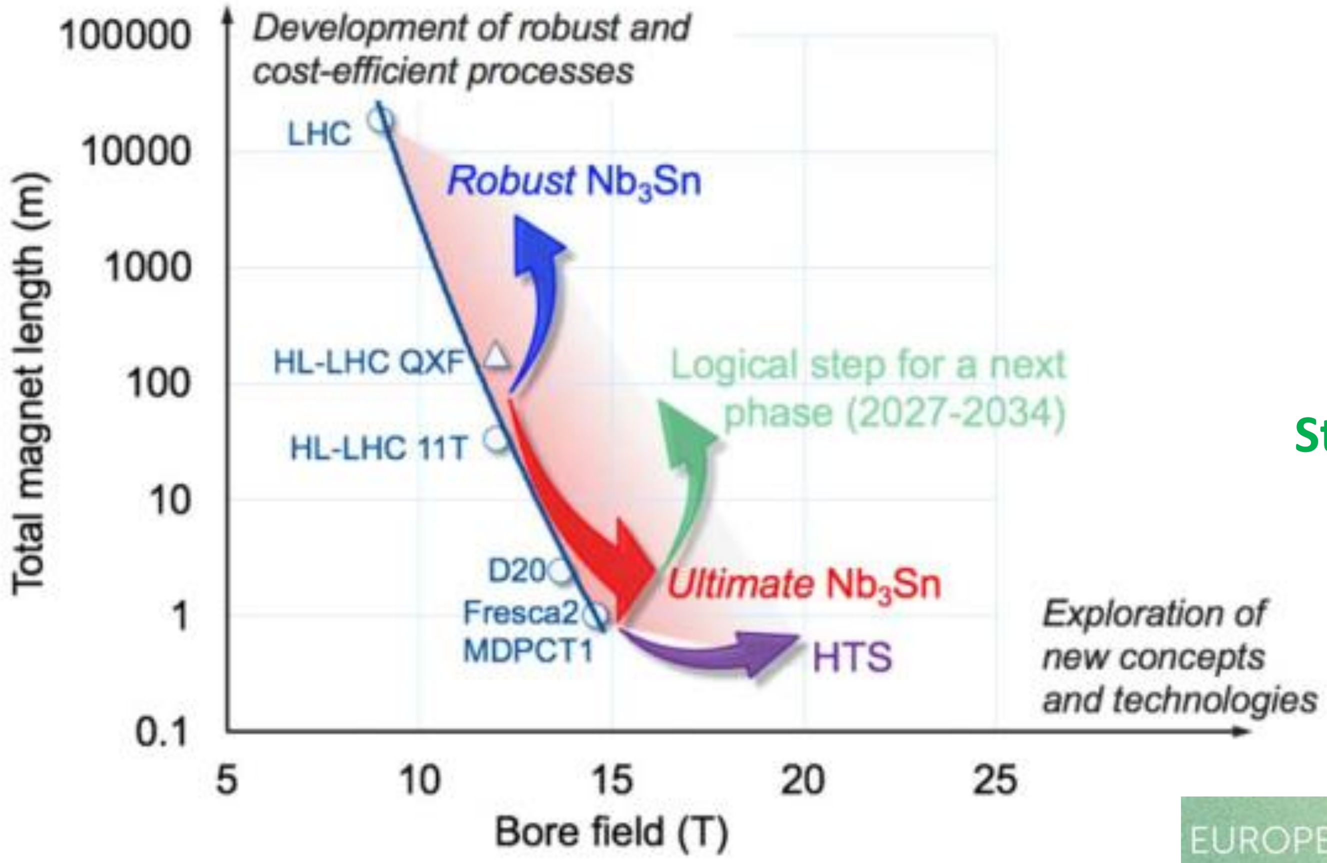
Abstract

The 2020 update of the European Strategy for Particle Physics emphasised the importance of an intensified and well-coordinated programme of accelerator R&D, supporting the design and delivery of future particle accelerators in a timely, affordable and sustainable way. This report sets out a roadmap for European accelerator R&D for the next five to ten years, covering five topical areas identified in the Strategy update. The R&D objectives include: improvement of the performance and cost-performance of magnet and radio-frequency acceleration systems; investigations of the potential of laser / plasma acceleration and energy-recovery linac techniques; and development of new concepts for muon beams and muon colliders. The goal of the roadmap is to document the collective view of the field on the next steps for the R&D programme, and to provide the evidence base to support subsequent decisions on prioritisation, resourcing and implementation.

The particle physics community should ramp up its R&D effort focused on advanced accelerator technologies.

The proposed R&D programme has two main objectives. The first is to demonstrate Nb_3Sn magnet technology for large-scale deployment. This will involve pushing it to its practical limits in terms of ultimate performance (towards the 16 T target required by FCC-hh), and moving towards production scale through robust design, industrial manufacturing processes and cost reduction, taking as a reference the HL-LHC magnets, i.e. 12 T). The second objective is to demonstrate the suitability of High-temperature superconductor (HTS) for accelerator magnet applications, providing a proof-of-principle of HTS magnet technology beyond the range of Nb_3Sn, with a target in excess of 20 T. The above goals are indicative, since the decision on a cost-effective and practical operating field will be one of the main outcomes of the development work.

High Field Magnet Program - R&D Objectives



Phase 1: 2022 -2027

Phase 2: 2027 -2034

Study feasibility of 20 T dipoles

TE-MSC Contribution to the HTS HFM Program

HTS Program

Conductor

- Procurement and qualification of HTS REBCO tape
- Development, assembly and qualification HTS REBCO cables (10 kA @ 4.5 K, 20 T)
- Development, assembly and test of racetrack coils (Wound Conductor Program)
- R&D on new materials (iron based)
- Upgrade of infrastructure for testing conductor in high fields (up to 20 T)

Magnets

- Racetrack coils optimized in Common-Coil magnet layouts (Short Model HTS Coils Program)
- Common-Coil Design
- HTS Demo(s)
  (5 T @ 4.5 K in a background field of 15 T)
- Upgrade of infrastructure for testing coils/inserts in background fields

TE-MSC Contribution to the HTS HFM Program